The UNDP Climate Change Country Profiles

Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries

BY C. McSweeney, M. New, G. Lizcano, and X. Lu

It is widely acknowledged that developing countries will suffer some of the greatest impacts of climate change due to their greater reliance on climate-dependent natural resources, and lack of finance and infrastructure for adaptation. However, the number of analyses of climate observations, climate model experiments, climate model projections, and climate change impacts studies that are based on developing countries is significantly smaller than in those which have been undertaken for more economically advanced countries. A 2006 *BAMS* article by Washington et al. demonstrates that only 10.7% of articles in the *Journal of Climate* and 25.6% of articles in the *International Journal of Climatology* published between 2002 and 2004 deal with climate research on Africa, the Middle East, Asia, and South America, while the overwhelming majority concern North America and Canada, Europe, and Australasia. This deficit in knowledge and information doubtlessly limits capacity for climate-related risk assessment, adaptation planning, and decision making in developing countries.

Climate change data generated using GCMs have been made increasingly available to other research groups outside of the major modeling centers through the progressive phases of the Coupled-Model Intercomparison Project (CMIP). The recent effort of the World Climate Research Programme (WCRP) in the run up to the IPCCs fourth assessment report has made available an "unprecedented collection" of over 35 TB of data from coordinated experiments using 23 different GCMs. This initiative has enabled a considerable body of research based on this data [over 500 publications listed on the Program for Climate Model Diagnosis and Intercomparison (PCMDI) Web site to date] and, perhaps most importantly, has considerably improved the ease with which multimodel projections can be assembled and used to add information about uncertainty in those projections that cannot be gained from using a single model. However, while these available data provide a rich opportunity for climate research, the computing facilities and expertise required for the transfer, storage, and manipulation of multiple files as large as these global data fields still inhibit their use where facilities, resources, and/or expertise are limited. This means that the number of analyses and applications of these climate data for developing countries still falls a long way short of those available for richer nations.

The relative shortage of data, expertise, and facilities available for climate science in developing countries cannot be addressed easily in the short term, but there are steps that can be taken to improve the availability of data that already exist for those countries. The objective of the United Nations Development Programme (UNDP) Climate Change Country Profiles project is to make use of existing data to generate a collection of country-level analyses of recent climate observations and the multimodel projections made available through the WCRP CMIP3. The project uses a consistent approach for all countries studied (listed in Table 1) to produce an "off the shelf" analysis of the

AFFILIATIONS: McSweeney and Lizcano—School of Geography and Environment, Oxford University, Oxford, United Kingdom; New—School of Geography and Environment, Oxford University, Oxford, United Kingdom, and Tyndall Centre for Climate Change Research, Oxford University, Oxford, United Kingdom; Lu—Environment and Energy Group, Bureau for Development Policy, United Nations Development Programme, New York, New York
CORRESPONDING AUTHOR: Mark New, School of Geography and Environment, Oxford University, South Parks Road, Oxford OX1 3QY, United Kingdom
E-mail: mark.new@geog.ox.ac.uk

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data to provide basic observed and model output summaries, and also make available the underlying data for each country in smaller—and thus more manageable—files for each country, and in text format that can easily be read and used with widely available software packages or simple text editors. By undertaking and disseminating basic analyses of observed data and model outputs, this project allows institutions or individuals undertaking further studies to make use of the information without bearing the burden of resourcing the considerable data processing involved in extracting the required information directly from multiple global fields from large data archives. We expect that this will encourage individuals to undertake studies that otherwise might not have been feasible in terms of the resources or facilities available, and also reduce the replication of similar analyses being undertaken by individuals and organizations, freeing resources for further studies and applications.

Table 1. Countries included in the UNDP Climate Change Country Profiles project.

Africa		Asia	Caribbean	Central America
Angola	Kenya	Afghanistan	Antigua and Barbuda	Belize
Benin	Malawi	Armenia	Barbados	Guyana
Cameroon	Mali	Cambodia	Cuba	Mexico
Cape Verde	Mauritania	Nepal	Dominica	Nicaragua
Chad	Mauritius	Pakistan	Dominican Republic	Suriname
Comoros	Morocco	Vietnam	Grenada	
Equatorial Guinea	Mozambique	Yemen	Jamaica	
Eritrea	Sao Tome and Principe		St Kitts and Nevis	
Ethiopia	Senegal		St Lucia	
Liberia	Tanzania		St Vincent and the Grenadines	
Sierra Leone	Togo		The Bahamas	
Ghana	Uganda		Trinidad and Tobago	
Gambia	Zambia			
Gabon				
Guinea				

DETAILS OF THE COUNTRY PROFILE CONTENTS. Each of the UNDP climate change country profiles includes the following elements, for a number of climate variables.

- A set of maps and diagrams demonstrating the observed and projected climates of that country:

  a) Country-average time series showing observed changes combined with projected changes under three of the Intergovernmental Panel on Climate Change (IPCC)'s Special Report on Emissions Scenarios (SRES) emissions scenarios (A2, A1B, and B1; see the 2000 published report by Nakicenovic et al. for further explanation of these scenarios). These time series depict the projected changes as a "plume" showing the ensemble range of the 15 models under each scenario, thereby illustrating the magnitude of projected changes and the level of model spread (indicative of model uncertainty) relating to each SRES emissions scenario.

  b) Maps depicting projected changes by 10-yr "time slices" for the 2030s, 2060s, and 2090s under SRES emissions scenario A2 on a 2.5° × 2.5° grid. For each grid box we give the ensemble median change and also the ensemble range across the 15 models.

- A summary table of observed trends and projected change, averaged over the whole country, for the 2030s, 2060s, and 2090s under SRES emissions scenarios A2, A1B, and B1.
- A narrative summarizing the data above and placing it in the context of the country's general climate and known inadequacies in climate model performance affecting that region.

Table 2. Observational data sources used in the UNDP Climate Change Country Profiles project.

Monthly temperature				
Climatic Research Unit	New et al. (2002)	Gridded station data	1961–2000	0.5° x 0.5°
University of Delaware	Matsuura and Willmott (2007a)	Gridded station data	1961–2006	0.5° x 0.5°
NCEP	Kalnay et al. (1996)	Reanalysis data	1960–2006	0.5° x 0.5°
ERA40	Uppala et al. (2005)	Reanalysis data	1960–2001	0.5° x 0.5°
Monthly precipitation				
Climatic Research Unit	New et al. (2002)	Gridded station data	1961–2000	0.5° x 0.5°
University of Delaware	Matsuura and Willmott (2007b)	Gridded station data	1961–2006	0.5° x 0.5°
Global Precipitation Climatology Centre	Adler et al. (2003)	Merged station and satellite data	1960–1979	2.5° x 2.5°
Daily extremes indices				
HadEX	Alexander et al. (2006)	Gridded extremes indices based on station data	1960–2003	2.5° x 3.75°

- A set of text files, held online, containing the underlying data used in the report, in a simple text format that can be imported into commonly used spreadsheet software for further analysis (http://country-profiles.geog.ox.ac.uk).
- A technical document, included as an appendix to each report, explaining how the data were analyzed and describing the formats of the underlying data files.

DATA ANALYSIS. Tables 2 and 3 detail the sources of observational and model outputs that are used in the UNDP Climate Change Country Profiles.

Climate model projections are based on the three of the IPCC's SRES emissions scenarios, A2, A1B, and B1, which can be broadly described as "High," "Medium," and "Low," respectively. Emissions scenarios allow us to explore potential future climates that arise as a result of different greenhouse gas emissions levels that might occur under hypothetical, but internally consistent, "storylines" of economic, technological, and sociological development. The three scenarios should all be considered to be equally plausible.

The climate variables included are mean temperature and precipitation, as well as seven indices of extreme climate that illustrate changes in the daily variability of temperature and precipitation. The extremes analyzed are a subset of those used by Alexander et al. in a 2006 *Journal of Geophysical Research* article: the frequency of "hot" days (TX90p), "cold" days (TX10p), "hot" nights (TN90p), and "cold" nights (TN10p) (where "hot" or "cold" is defined by the temperature exceeded on 10% of observed days in the "present day" reference period); the proportion of rainfall that occurs in "heavy" events (R95p) (where a "heavy" event is defined by the daily rainfall total exceeded on 5% of days in the reference period); and the magnitude of maximum 1- and 5-day rainfalls (RX1 and RX5).

Table 3. GCMs included in UNDP Climate Change Country Profiles. For further details of each mode, refer to Randall et al. (2007), pp. 597–599.

Model	Institute
bccr_bcm2_0	Bjerknes Centre for Climate Research, Norway
cccma_cgcm3_1	Canadian Centre for Climate Modelling and Analysis
cnrm_cm3	MeteoFrance/Centre National de Recherches Meteorologiques, France
csiro_mk3_0	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia
csiro_mk3_5	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia
gfdl_cm2_0	U.S. Department of Commerce/ National Oceanic and Atmospheric Sciences Geophysical Fluid Dynamics Laboratory
gfdl_cm2_1	U.S. Department of Commerce/ National Oceanic and Atmospheric Sciences Geophysical Fluid Dynamics Laboratory
giss_model_e_r	NASA/ Goddard Institute for Space Studies (GISS), USA
inmcm3_0	Institute for Numerical Mathematics, Russia
ipsl_cm4	Institute Pierre Simon LaPlace, France
miub_echo_g	Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea
mpi_echam5	Max Plank Institute for Meteorology, Germany
mri_cgcm2_3_2a	Meteorological Research Institute, Japan
ncar_ccsm3_0	National Center for Atmospheric Research, USA
ukmo_hadcm3	Hadley Centre for Climate Prediction and Research/Met Office, UK

Table 4 (opposing page). Example data summary table for temperature and precipitation for Kenya. Asterisk indicates trend is statistically significant at 95% confidence. Similar tables are included in all reports for observed and projected changes in extremes indices.

Values are expressed as anomalies from the 1970–99 mean climate (the most recent 30-yr averaging period), with the exception of the temperature extremes indices (TX10p, TX90p, TN10p, TN90p), as these values already represent a relative measure. The observed extremes indices, which are derived from the HadEX gridded dataset, have already been calculated using 1961–90 as the standard climate reference period, and the nature of the data mean that reexpression using a more recent reference period is not possible. However, we quote the frequency with which the percentile thresholds are exceeded in the period 1970–99 in the summary tables to indicate how much of a discrepancy this causes. Further, GCM daily data required to calculate extremes indices are only available for two periods in the future from the CMIP3 data site—2045–64 and 2080–99—so projections of changes in extremes are restricted to these two time periods.

All data are presented as annual and seasonal means, with seasons defined according to each country's specific climate rather than limiting the study to fixed standard 3-month seasons. The observed time series are calculated as a mean of the different contributing datasets for each variable (data are provided in text files as both individual dataset time series and the multidataset-mean time series). GCM time series are created by first being regridded from their native resolution to a common 2.5° × 2.5° lat/lon grid before selecting grid boxes that lie ei-

KENYA												
	Observed mean 1970–99	Observed trend 1960–2006	SRES	Projected changes by the:								
				2030s			2060s			2090s		
				Min	Median	Max	Min	Median	Max	Min	Median	Max
Temperature												
	°C	Change (°C decade⁻¹)		Change (°C)			Change (°C)			Change (°C)		
			A2	0.9	1.2	1.5	1.8	2.4	2.8	2.8	3.7	4.5
Annual	23.9	0.21*	A1B	0.8	1.2	1.5	1.6	2.3	2.7	2.3	3.0	4.0
			B1	0.5	1.0	1.2	1.0	1.7	2.0	1.3	2.0	2.6
			A2	0.7	1.2	1.6	1.4	2.2	3.1	2.4	3.6	4.6
JF	25.1	0.22*	A1B	0.6	1.1	1.6	1.7	2.3	2.8	2.1	3.1	4.1
			B1	0.4	1.0	1.3	1.0	1.5	2.2	1.1	1.9	2.6
			A2	1.0	1.2	1.8	1.8	2.4	2.7	2.9	3.8	4.5
MAM	24.6	0.29*	A1B	0.5	1.3	1.6	1.6	2.3	2.7	2.3	3.0	3.9
			B1	0.5	1.0	1.5	1.1	1.6	2.0	1.4	2.1	2.8
			A2	0.9	1.2	1.6	1.9	2.5	2.8	3.0	3.9	4.7
JJAS	22.7	0.17*	A1B	0.8	1.3	1.7	1.6	2.4	2.7	2.3	3.2	4.4
			B1	0.6	1.1	1.3	1.0	1.7	2.1	1.5	2.1	2.7
			A2	0.6	1.1	1.3	1.7	2.2	2.8	2.6	3.4	4.3
OND	23.9	0.19*	A1B	0.8	1.1	1.3	1.4	2.1	2.6	2.0	2.7	3.8
			B1	0.2	0.9	1.2	0.8	1.5	2.0	1.2	1.8	2.5
Precipitation												
	mm month⁻¹	Change (mm decade⁻¹)		Change (mm month⁻¹)			Change (mm month⁻¹)			Change (mm month⁻¹)		
			A2	−1	3	11	0	5	20	3	13	27
Annual	57.3	−1.5	A1B	−3	4	12	0	7	16	1	10	21
			B1	−3	2	10	−4	4	10	−1	5	15
			A2	−8	2	11	0	5	23	0	17	30
JF	29.0	−1.0	A1B	−3	6	17	−2	3	25	−4	10	20
			B1	−11	2	17	−3	6	14	−3	5	19
			A2	−12	3	18	−12	9	31	−12	15	47
MAM	95.7	−3.7	A1B	−8	7	21	−7	9	29	−13	12	35
			B1	−13	0	19	−8	2	23	−7	5	23
			A2	−5	0	12	−5	0	12	−2	3	22
JJAS	34.6	−0.8	A1B	−8	0	6	−5	1	11	−3	1	13
			B1	−4	0	7	−8	0	8	−4	2	6
			A2	0	11	19	−3	13	33	5	29	49
OND	67.2	−0.6	A1B	−6	8	29	0	9	30	6	21	32
			B1	−5	4	22	−8	12	19	−3	13	37
Precipitation (%)												
	mm month⁻¹	Change (% decade⁻¹)		% change			% change			% change		
			A2	−2	5	14	0	8	24	5	20	48
Annual	57.3	−2.6	A1B	−5	6	17	0	8	26	2	15	30
			B1	−3	2	12	−6	6	19	−1	10	19
			A2	−11	6	26	−3	11	49	0	27	89
JF	29.0	−3.5	A1B	−14	11	50	−6	9	60	−7	20	58
			B1	−16	5	21	−4	12	43	−5	16	29
			A2	−16	3	14	−27	8	40	−17	19	60
MAM	95.7	−3.9	A1B	−9	5	27	−7	10	37	−18	10	45
			B1	−17	0	26	−7	3	31	−5	4	37
			A2	−7	−1	26	−13	0	25	−4	11	46
JJAS	34.6	−2.4	A1B	−18	1	24	−7	5	28	−6	3	27
			B1	−9	1	15	−17	2	27	−8	5	17
			A2	0	11	16	−4	13	32	6	27	48
OND	67.2	−0.8	A1B	−4	8	20	0	12	29	7	19	36
			B1	−6	4	29	−9	12	18	−2	14	26

ther wholly or partially within each country's political boundaries to contribute to the country average, and then using the median, minimum, and maximum value for each year and each emissions scenario to create the time series "plumes."

Further details of the methods employed in the data analysis are provided in the documentation available from the project Web site (http://country-profiles.geog.ox.ac.uk).

PRESENTATION OF THE ANALYSES. Some examples of the figures and summary tables are shown in Figs. 1–6 and Table 4, using Kenya for illustrative purposes. The full reports include similar figures for each season and parameter. The figures shown here include cases where climate model projections are more consistent, and where regions or particular parameters are more uncertain. For example, the precipitation changes in the time series in Fig. 3 show that both increases and decreases in precipitation are projected, depending on the model analyzed, but there is a tendency toward increases in total annual precipitation. These results are quantified in Table 4, which shows that the changes in annual precipitation simulated for Kenya by the 2090s range from +5% to +48% under SRES-A2, +2% to +30% under SRES-A1B, and −1% to +19% under SRES-B1. Figure 4 then shows the spatial pattern of mean changes for specific 10-yr periods, again being careful to include both mean change and the range across the ensemble.

The distinct changes in daily extremes in observations and projections are evident in Figs. 5 and 6. "Hot" nights tend to show the largest changes in both observations and projections in many countries. The time series for Kenya in Fig. 5 show particularly steep rates of increase in frequency since the early 1990s. Projected changes are also large, but the figures demonstrate the large range of model uncertainty associated with these daily extremes. These events, occurring approximately 10% of the time in 1970–99, are projected to occur on 77%–95% of days by the 2090s under SRES-A2, 64%–93% of days under SRES-A1B, and 40%–73% of days under SRES-B1.

Note that in the case of RX1 and RX5 we do not show the observed values overlaid on the model projection in time series plots. This is because the magnitude of rainfall extremes at observation stations (points) does not compare with the magnitude of areal-average (grid cell) rainfall extremes in model simulations. In the case of the other extremes indices, there may be disparities in the magnitudes of point and areal average represented by the different spatial scales of the information, but it is the direction and magnitude of the trend rather than the values with which we are primarily concerned.

COUNTRY DATA FILES. The underlying data behind the figures and tables for each country are also made available in a text format. Observed data are provided as time series for every season in absolute as well as anomalies relative to the 1970–99 mean. For temperature and precipitation we also provide a 1970–99 climatology extracted from the CRU datasets and regridded to the same 2.5° × 2.5° lat/lon grid that is used for the model data, allowing it to be combined easily with the simulated changes. Model data are provided both as country average time series data for each season as well as 10-yr average "time slice" files with values for each 2.5° × 2.5° grid box for a rectangular area encompassing the whole country. We provide data for each individual model in the ensemble as well as the ensemble median, minimum, and maximum.

"APPROPRIATE" APPLICATIONS. While encouraging the use of observed and model-simulated climate projections, we also remain sensitive to the limitations of these outputs and the potential inappropriate use and overinterpretation of such data that are inevitably facilitated via its wide circulation. We stress that these brief summaries are not a substitute for comprehensive, locally led assessments of climate change risk that should draw on a considerably wider range on information sources, including local expertise on specific social and physical vulnerabilities. These profiles should not be used as a sole information source for decision making, but instead act as a "stepping stone" in contributing to, and facilitating, climate impact studies and vulnerability assessments that make up the body of information available for consideration by those involved in decision making.

Appropriate applications for the UNDP climate change country profiles might include:

- Provision of contributing information to those comprehensive, locally led climate risk analyses, where the data are interpreted by local climate experts with due attention to the limitations of climate model projections (discussed further below) and local contextual information.

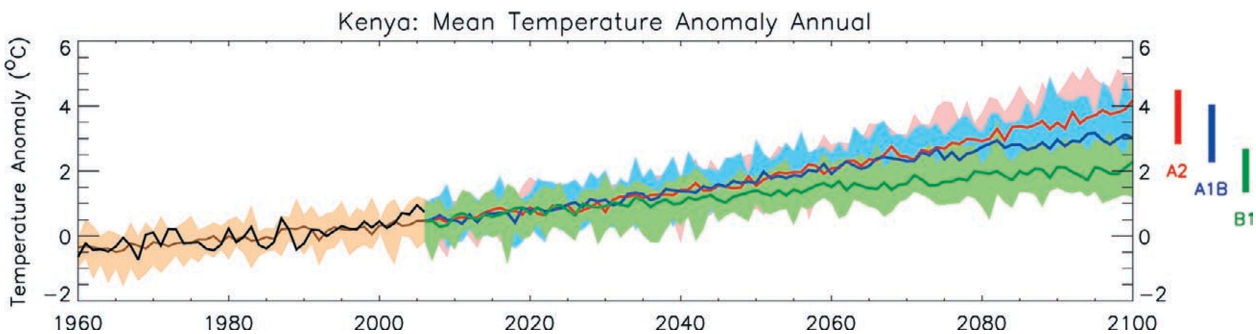

Fig. 1. Example temperature anomaly time series for Kenya. All values shown are in anomalies from the 1970–99 mean climate. Black curves show the mean of observed trends from 1960 to 2006. Brown curves and shading show the median and range of results from multi-GCM simulations of past climate. Colored lines and shading from 2007 onward show multimodel ensemble median and range of projected climate under three emissions scenarios. Colored bars on right hand of projections show range of model projections averaged over 2091–2100 for each emissions scenario.

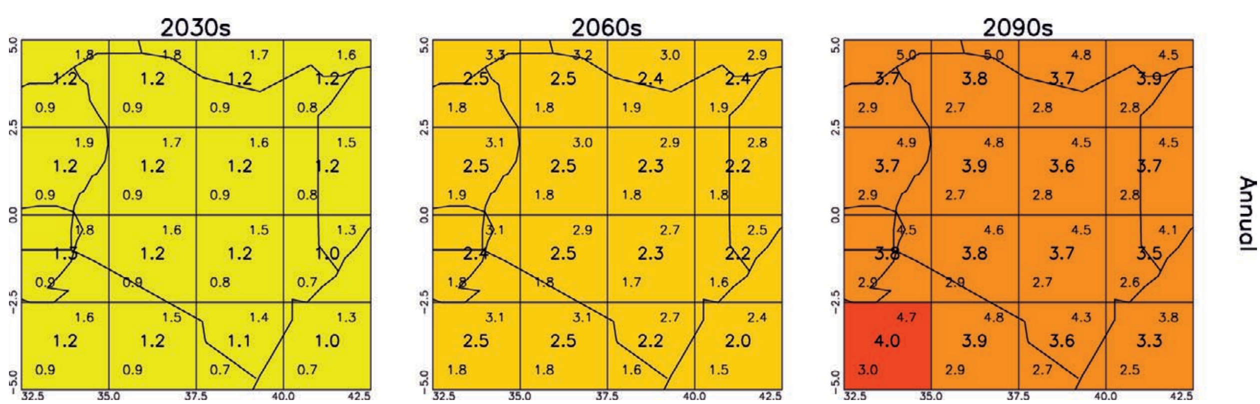

Fig. 2. Example maps for Kenya showing patterns of projected change in mean annual temperature (°C) for 10-yr periods in the future under SRES-A2 scenario. All values are relative to the mean climate of 1970–99. In each grid box, the central value and color give the multimodel ensemble median, and the values in the upper and lower corners give the ensemble maximum and minimum.

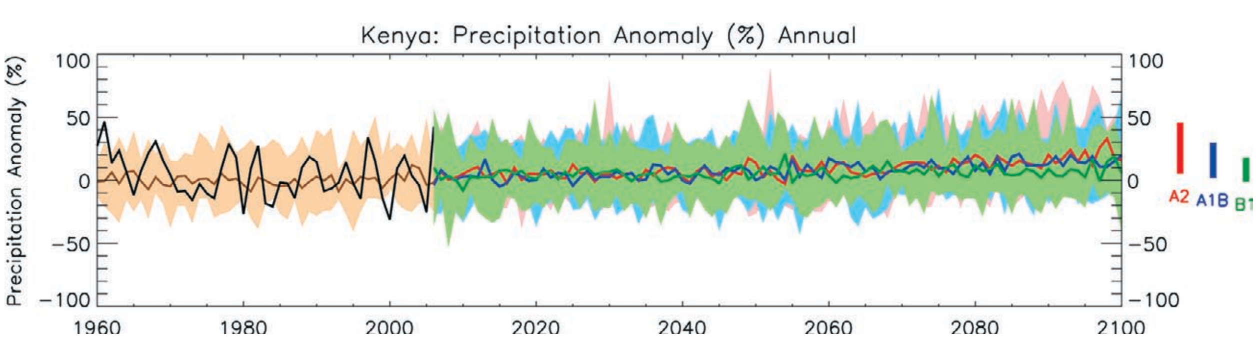

Fig. 3. Example precipitation percentage anomaly time series for Kenya. All values shown are in percentage anomalies from the 1970–99 mean climate. Black curves show the mean of observed trends from 1960 to 2006. Brown curves and shading show the median and range of results from multi-GCM simulations of past climate. Colored lines and shading from 2007 onward show multimodel ensemble median and range of projected climate under three emissions scenarios. Colored bars on right hand of projections show range of model projections averaged over 2091–2100 for each emissions scenario.

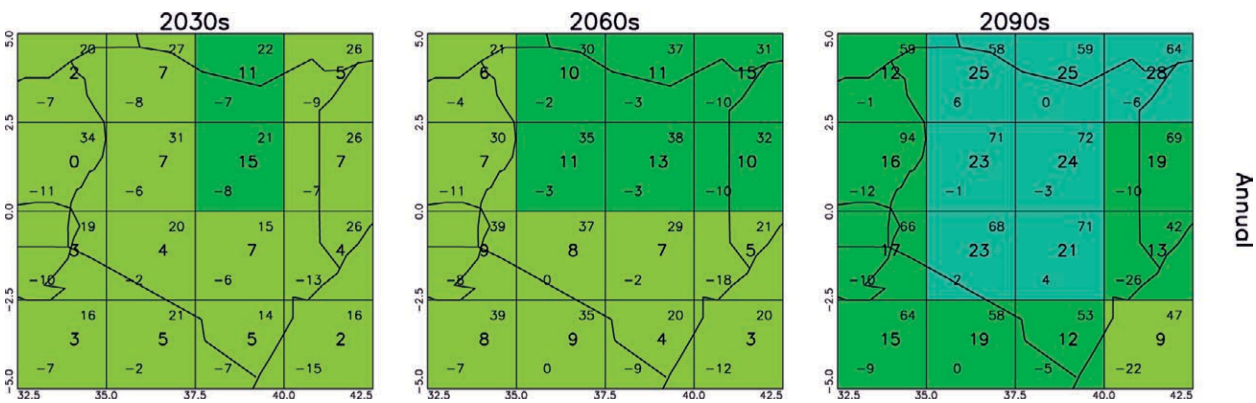

Fig. 4. Example maps for Kenya showing patterns of projected change in mean annual precipitation (%) for 10-yr periods in the future under SRES-A2 scenario. All values are relative to the mean climate of 1970–99. In each grid box, the central value gives the multimodel ensemble median, and the values in the upper and lower corners give the ensemble maximum and minimum.

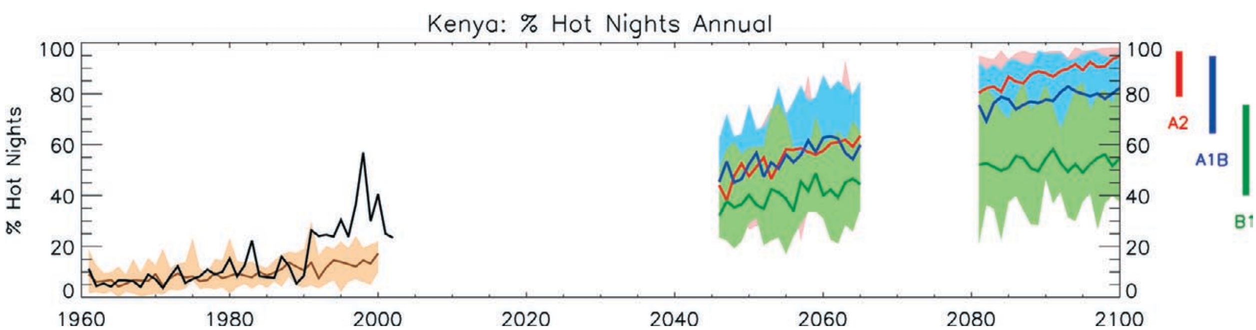

Fig. 5. Example hot-night frequency time series for Kenya. Black curves show the mean of observed trends from 1960 to 2006. Brown curves and shading show the median and range of results from multi-GCM simulations of past climate. Colored lines and shading from 2007 onward show multimodel ensemble median and range of projected climate under three emissions scenarios. Incomplete time series are shown for the extremes data as WCRP CMIP data is only available for these two 20-yr time periods. Colored bars on right hand of projections show range of model projections averaged over 2091–2100 for each emissions scenario.

- Provision of driving climate data for exploratory climate impacts assessments that help to identify local vulnerabilities—for example, studies assessing potential future changes in water resource availability, or investigation of the possible responses of crops to changing climate conditions.
- Identification of specific areas of vulnerability that demand further investigation—for example, countries for which the GCM ensemble projects particularly large increases in extreme rainfalls may choose to direct their resources to this field, by commissioning more in-depth analyses of rainfall regimes in observed and simulated climate, impact assessments, or hydrological modeling experiments.

KEY ASSUMPTIONS AND LIMITATIONS. Inherent in any of the proposed applications is a necessary understanding and due acknowledgment of the limitations of climate model projections. While GCMs have demonstrable skill in reproducing the large-scale characteristics of the global climate dynamics, there remain substantial deficiencies that arise from limitations in resolution imposed by available computing power, and deficiencies in scientific understanding of some processes. The IPCC provides a summary of those elements of climate models in which we can have some confidence, and those areas of remaining deficiencies, to which we would point the reader for guidance. Some key deficiencies which are particularly relevant to some of those countries included in the UNDP Climate Change Country Profiles are:

- The coarse spatial scale that prevents the representation of small island land masses, such as those of the Caribbean.
- Difficulties in reproducing the characteristics of the El Niño/Southern Oscillation, which exerts a strong influence on the interannual and multiyear variability in climate in many regions.
- Deficiencies in reliably simulating tropical precipitation, particularly the position of the Intertropical Convergence Zone (ITCZ), which drives the seasonal rainfalls in the Tropics.

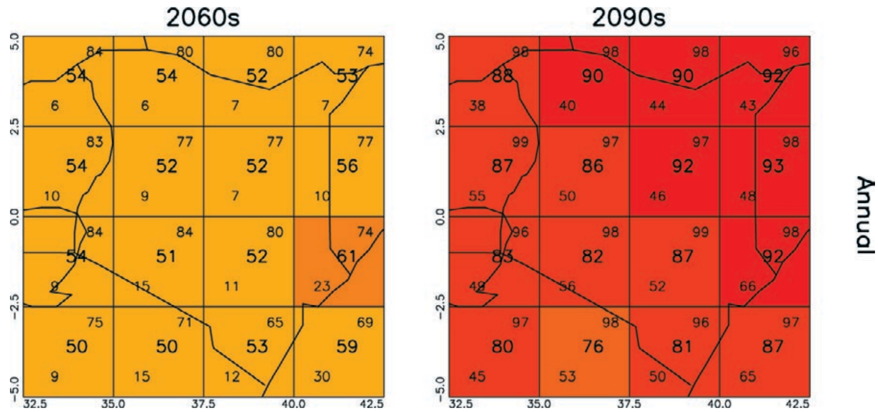

Fig. 6. Example maps for Kenya showing patterns of projected change in hot night frequency (TN90p) for 10-yr periods in the future under SRES-A2 scenario. In each grid box, the central value gives the multimodel ensemble median, and the values in the upper and lower corners give the ensemble maximum and minimum.

An inherent assumption made in the use of a multimodel ensemble range—as in these profiles—is that the degree of model spread is indicative of the level of uncertainty in the set of projections. While the degree of divergence between projections from different models is considered to reflect the level of confidence in model performance in some regions, variables, seasons, or particular features of the climate system, users should be aware of the potential pitfalls of assuming that model consensus implies lower uncertainty in those projections. A multimodel experiment such as this reflects the level of scientific understanding and technical capabilities at one point in time; the characteristics of the projected changes, as well as the level of consensus between models, can be considered as a "snapshot" of the uncertainty that relates to the process of climate modelling rather than a "fixed" measure of total uncertainty in climate response.

We also acknowledge the limitation imposed by limited observational data coverage for many developing areas of the world, and thus their underrepresentation in the global gridded datasets (see Table 2) that we draw on to identify trends in recent climate. For countries where Alexander et al. (2006) were unable to gather sufficient daily data to calculate extremes indices, we are unable to include this information in our country profiles. For some countries, these trend analyses will be based on data that provide incomplete spatial coverage of that country.

SUMMARY. The UNDP Climate Change Country Profiles project contributes a source of observational climate data and model output on a country-by-country basis that can be consulted in investigations of climate impacts, risk assessments, or adaptation options and in directing resources to topics on which further exploration might be most beneficial. We provide basic analyses of these data in the form of narrative, data tables, and graphics as an "off the shelf" resource, as well as providing the underlying data for those analyses in an easy-to-use format in order to facilitate further analyses and application.

While this project makes available information that can be very valuable when used appropriately, it is important to note that significant limitations and caveats are involved wherever climate model projections are applied. We remind users of these country profiles of the importance of (a) drawing on a wide range of information sources in investigations of climate change and its implications; (b) paying due attention to the limitations of climate model projections that arise due to incomplete understanding of the climate system and coarse spatial resolution; and (c) paying due attention to the limitations of incomplete spatial coverage of observational data in many developing regions.

A proposed second phase of the project will hopefully extend this project to produce climate change profiles for all developing countries. All reports and data are available online at http://country-profiles.geog.ox.ac.uk.

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FOR FURTHER READING

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